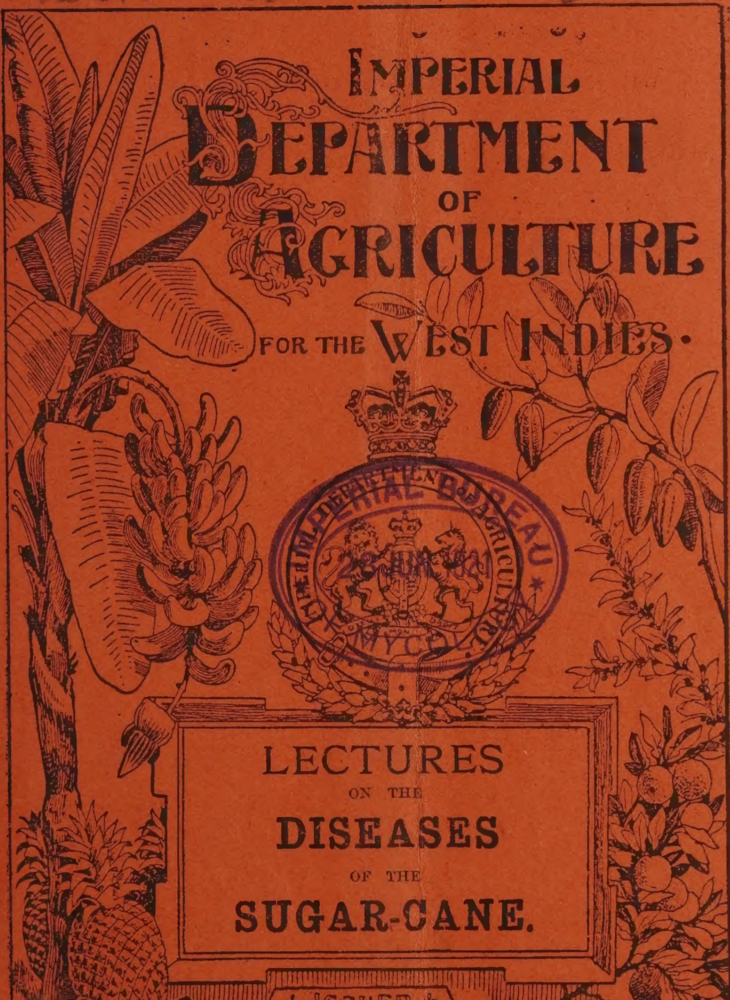
Lewton-Brain A D Cotton



IMPERIAL DEPARTMENT OF AGRICULTURE FOR THE WEST INDIES.

LECTURES ON THE DISEASES OF THE SUGAR-CANE.

ISSUED BY THE COMMISSIONER.

1904.

No. 29.] [Price Four-pence.

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Pamphlet Series,
No. 29.

IMPERIAL

DEPARTMENT OF AGRICULTURE

FOR THE WEST INDIES.

LECTURES

ON THE

DISEASES

OF THE

SUGAR-CANE.

By L. Lewton-Brain, B.A., F.L.S.,

Mycologist and Lecturer in Agriculture on the staff of the Imperial Department of Agriculture.

ISSUED BY THE COMMISSIONER OF AGRICULTURE.

1904.

PREFACE.

The following pages contain the substance of three lectures, recently delivered before the members of the Barbados General Agricultural Society, on some fungoid diseases of the sugar-cane, by Mr. L. Lewton-Brain, B.A., F.L.S., Mycologist on the staff of the Imperial Department of Agriculture.

The diseases referred to attack canes to a greater or less extent in all the sugar-producing colonies in the West Indies. The root disease (*Marasmius*) was especially prevalent at Barbados last year, and it was largely due to the attacks of this fungus that the sugar crop of 1903 (35,000 hhds.) was lower than any during a period of thirty-four years. It was even lower than in 1895, when the ravages of the rind fungus (*Trichosphaeria*) reduced the normal crop of 56,000 hhds. to 36,000 hhds. and led to the practical abandonment of the Bourbon cane. The principal canes now cultivated are the White Transparent and seedling canes.

A conservative estimate, after making every allowance for unfavourable seasons and other circumstances, has placed the loss due to the attacks of fungoid diseases at Barbados during 1903 at 10,000 hhds. of the value of £70,000. If we take into account the loss sustained in molasses also, the total loss in 1903 would not fall far short of £100,000. It was with the view of aiding the planter to control the diseases affecting his crops, especially in these days of low prices, that the lectures delivered by Mr. Lewton-Brain were

organized. If the advice given in the lectures be closely followed, there is little doubt that the loss likely to be sustained from the attacks of cane diseases might be reduced at least one-half. It is hoped, in view of these facts, that the recommendations of the Department will receive the hearty support of all members of the planting community.

The root fungus is present again this year, but, owing to the greater vigour of the canes due to favourable seasons, the effects are not so marked as last year. It is recommended that tops for planting should be selected from healthy canes only ; that where the disease shows itself in small patches in the fields, these should be isolated by a trench (about a foot deep) dug round them, so as to prevent the disease from passing through the soil and attacking healthy canes ; that all cane stumps whatsoever should be dug up and destroyed either by burning or being heaped up and treated with quicklime ; and that where a field has been very badly attacked by root disease it should be thrown out of cultivation in canes, treated with lime, and planted with other crops for a period of at least one year—preferably two years.

These recommendations are of so simple and practical a character that no difficulty need be experienced in carrying them out ; and especially, as the probability is, that they would be the means of saving a considerable portion of the loss to the sugar industry of this island which was estimated last year by responsible officers of the Department at £100,000.

D. MORRIS,

Commissioner of Agriculture
for the West Indies.

February 19, 1904.

DISEASES

OF THE

SUGAR-CANE.

LECTURE I.

In to-day's lecture I do not intend to deal definitely with any diseases of the sugar-cane. In the first place I wish to go briefly into the structure of a living sugar-cane plant, then to explain, also briefly, the functions of the various parts of the plant.

I think this plan advisable for two reasons :— Firstly, unless one knows something of the structure of the plant, it will be exceedingly difficult to understand in what ways the parasitic fungi, that bring about sugar-cane diseases, enter and live in the plant; also, unless one knows the functions of the various plant structures, and what part they play in the economy of the plant, I do not see how anyone can understand the way in which a fungus causes disease by attacking one or other of the organs of a plant.

Secondly, in order to understand why a fungus damages its host plant, it is necessary to know what food a fungus needs, and how it obtains it, and the best way to learn this is to study the way in which an ordinary green plant gets its food materials and works them up, and then to compare the fungus with it.

Let us then take the sugar-cane plant, see what organs it possesses, find out what their structure is, study their functions and see how they perform them.

THE EXTERNAL FEATURES OF THE SUGAR-CANE.

As you know, the sugar-cane, like all ordinary green plants, may be divided in two parts—a root part which grows down into the soil, and a shoot part that grows up into the air. The shoot part consists of a central portion, the stem, on which leaves are borne laterally. The shoot part also bears the flowers, but as these are not of importance in connexion with sugar-cane diseases we will not consider them.

ROOT OF SUGAR-CANE.

The roots of the sugar-cane differ considerably from those of, say, the cotton and other plants, belonging to the large class of Dicotyledons. In these, there is one main root going straight down into the soil, and from this a number of branch roots are given off which spread laterally, from these other branch roots, which spread in other directions, and so on. All these roots are continually increasing both in thickness and length. In the sugar-cane and other plants belonging to the class of Monocotyledons there is no main root and no branches. In place of this system we get a large number of roots quite independent of one another which all grow more or less straight down into the soil, which never grow to any great size and which never branch. These roots spring in great numbers from the base of the stem, and as older roots reach their limit of growth and die away, other roots grow out from the stem to replace them.

The only other point to notice about the roots are the root-hairs. These are very tiny, delicate, white hairs, which grow out, in large numbers together, from a point just behind the tip of the root. As the root gets older these die away, and their place is taken by other root-hairs, formed nearer to the tip, and this process continues all the time the root is alive.

STEM OF SUGAR-CANE.

The stem is, while young, covered by the sheathing bases of the leaves. It possesses a number of joints or nodes, and between these we have the smooth internodes. The internodes become shorter, and the nodes closer together, as we get nearer the tip of the stem. From the nodes arise the leaves, and, in the corner between the leaf and the stem, arise buds. As a general rule, only those buds near or in the soil develop, but every one is capable, given the proper conditions, of growing out into a branch like the parent stem. It is from the nodes also that the roots arise, several from each node; they are at first covered by the leaf bases. Unlike the buds they arise all around the stem, and if they are examined closely may be seen to arise from the inside of the stem and to have to force their way through the outer tissues.

LEAF OF SUGAR-CANE.

The leaves of the sugar-cane are much like those of other grasses. They are composed of two parts, the leaf base and the blade. The leaf base is large and forms a sheath to the stem. The blade is linear, the veins run parallel from base to apex, and the margin of the blade is rough to the touch owing to a number of minute prickles along the edge. Another interesting point about the leaf of the sugar-cane is

the fact that in dry weather the blade rolls up, forming a tube, with the upper surface of the leaf inside. As we shall see later, this is an adaptation to prevent excessive loss of water from the leaves, such as might take place when both air and soil were dry.

THE INTERNAL STRUCTURE OF THE SUGAR-CANE.

Let us now briefly examine the structure of the various parts. As you are doubtless aware, all plants are made up of small bags called cells; these cells are packed closely together, and have different shapes and structures according to the different functions they have to perform.

STRUCTURE OF ROOT.

If we cut across the root of the sugar-cane and examine the structure under a microscope, we shall see at once that the root is divided into two parts; there is an outer part where the cells are all more or less alike, thin-walled and closely packed, then there is a central cylinder where we get several different kinds of cells. The cells of the central cylinder are mostly smaller than those of the outer part, and are more closely packed together. The most important of these, for our present purpose, are larger, thick-walled cells which are arranged in groups, or rather strands, because these strands are continuous right through the length of the roots and, moreover, are also continuous with similar strands which we shall meet with in the stem and leaves. These cells are different from ordinary cells in shape, being very much longer than broad, they are, in fact, tubes—hollow pipes—formed by the fusion of several cells placed one above

the other. Their walls are thickened and variously marked and they also become woody and hard. The chief point I wish you to remember is that here we have a complete system of tubes, starting in the roots, running up right through the stems and into the leaves. These tubes are called vessels.

Now let us examine the structure of a root a short distance behind the growing point, that part, you remember, on which root-hairs occur. The general structure here is much the same except that the wood vessels are less developed. But from the outermost layer of cells we find, growing out, very delicate thin-walled prolongations—the root-hairs. These grow out into the soil and become very closely attached to the particles of soil, while their walls become somewhat gelatinous. So you see there is a very close connexion here between the plant and the soil.

ROOT-TIP.

We will now have a look at the structure of the actual tip of the root itself. The actual tip of the root is covered over by a cap of cells which are loosely arranged and are dead, this is the root-cap and its function is to protect the delicate tip from injury. The root-tip itself is composed of small cells which are all alike, their walls are thin and they are full of living matter, protoplasm. These cells are all actively dividing and this is the only part of the root where new cells are formed, so you see, if anything happened to this growing point, all growth of the root would be stopped and the root would remain short. As new cells are constantly being added, behind, by the growing tip, this is constantly being pushed forwards into the soil and it is for this reason that it needs the protective root cap.

STRUCTURE OF STEM.

The structure of the stem need not detain us long, but there are one or two points to be noticed. On cutting across the stem, we see no division between central cylinder and outer part, as we did in the root. The wood vessels again are arranged in strands, but these strands are scattered irregularly about the section. The space between the strands is filled up with ordinary, thin-walled cells. These strands, as you remember, are continuous with those of the roots. On the outside of the whole stem we get a layer of special tabular cells, the epidermis. The outer walls of these cells are much thickened, and besides are chemically changed in such a way as to be quite impervious to water. The functions of this layer of cells are first to prevent the loss of water by evaporation from the stem, which would cause the plant to dry up, and second, to shield the soft tissues inside from the attacks of insect and fungoid parasites. Under the epidermis we get several layers of cells, with very hard, thick, woody walls ; these cells are mechanical tissue and they serve to strengthen the stem and so prevent its being broken by the wind or otherwise.

STRUCTURE OF LEAF.

The structure of the leaf is fairly simple. If we examine a section we see on the outside, on each surface, an epidermis like that of the stem and, like that, impervious to gases and to water. On the leaf, however, we get special openings between some of the cells, these openings are the stomata. Each stoma is enclosed by a pair of special sausage-shaped cells, known as guard cells, which differ from the ordinary cells of the epidermis in containing some green

colouring matter. The stomata in the sugar-cane leaf are arranged in rows down the blade, and are mainly on the upper surface. As you will see at once, the stomata are of great importance, as they are the only means of communication between the tissues inside the plant and the outer air. The main body of the leaf is made up of thin-walled cells, packed so as to leave spaces between; these spaces are continuous throughout the leaf and open to the outer air at the stomata. The cells themselves are characterized by the possession of small bodies, specialized parts of the protoplasm, which contain a green colouring matter. In this tissue we find the strands with the wood vessels; these strands pass straight through the leaf, and at the base pass into the stem and become continuous with the strands we found there.

THE NUTRITION OF THE SUGAR-CANE.

Having thus briefly reviewed the chief organs of the sugar-cane plant and their structure, let us go on to see what part they play in the life of the plant.

In order to live and to carry on the processes of life a plant, like an animal, requires to take in certain substances as food, among which these are the most important:—

Lime, Magnesia, Potash, Iron, Sulphates, Phosphates, Nitrates, Carbon, Water.

Of course the plant does not take in these as such; the potash for instance may be taken in as chloride, sulphate or nitrate of potash, and so on.

Now there are two possible sources from which the plant might obtain its food—the soil and the air. It is connected

very intimately with the soil by means of its root hairs, and with the air by means of the stomata on the leaves.

ABSORPTION OF FOOD FROM THE SOIL.

It has been found by experiments that all these substances, with the exception of carbon, are taken up from the soil, while the carbon is taken from the air.

You will remember how intimately the root-hairs are connected with the soil particles, practically becoming fused with them. Now these soil particles are covered with a very fine film of water. This water of course is not pure, it contains dissolved in it very small quantities of all the soluble bodies which it has come in contact with; amongst them are various salts, compounds of potash, nitrates, phosphates, etc.

This water then, with the various food salts dissolved in it, passes through the very delicate walls of the root-hairs, and is so taken in by the plant. From the root-hairs it is passed through the tissues of the root, until it reaches the central cylinder and the wood vessels. You remember these vessels are long tubes, and that there is a continuous system of them right through the plant. It is in these vessels that the water current travels from the roots, through the stem and into the leaves; when it reaches the leaves it is distributed—still containing the food salts in solution—to the green cells of the leaf. Some of the water is used up by the plant in the leaves, but the plant has to take in a good deal more than it actually needs; the water contains very small quantities of food salts and to get enough of these for its wants, the plant has to take in very large quantities of water.

GIVING OFF EXCESS WATER.

The excess water is got rid of by the leaves; it soaks through the thin walls of the green cells, and evaporates into the spaces between the cells; it passes from these into the outer air through the stomata. This is the process of transpiration and is, you see, merely one of evaporation. It is evident that the rate at which it takes place depends on external conditions. If the air be very dry, or if the wind be blowing, transpiration will be increased. Sometimes, especially if the soil be dry, the water evaporated from the leaves exceeds that which the roots take up from the soil; under these conditions the plant wilts, the leaves droop, and so on. Many plants have adaptations to prevent this excessive loss of water in transpiration, but I need only mention that possessed by the sugar-cane. Here the leaves roll up into a scroll, in such a way that the upper surface forms the lining of a hollow tube. In this way, the stomata, which you remember are mostly on the upper surface, are protected from the wind and the sun. And so evaporation is checked.

ABSORPTION OF FOOD FROM THE AIR.

We have now traced that part of the plant's food which it obtains from the soil up from the root-hairs to the green cells of the leaf. This food consists of water with the various mineral salts in solution. We will now study the taking in of plant food from the air.

It was at one time thought that plants obtained their carbon like their other foods from the soil, and in an old book I have on agricultural chemistry the author recommends adding large quantities of blubber to the soil to increase the

supply of carbon there. It was easily proved, however, by growing plants in soil free from carbon, that they could obtain all they want of this element from the air.

In the air, carbon exists in combination with oxygen as carbon dioxide. This passes, with the other gases of the air, into the leaf by the stomata and into the spaces between the cells. From these spaces it passes into the green cells of the leaf through their cell walls.

ASSIMILATION OF CARBON.

Now in the cell we have the water and food-salts brought up from the soil. Under the influence of sunlight, chemical changes go on between the carbon dioxide and the water, which result finally in the production of sugar. During this process oxygen is split off and is given out into the intercellular spaces of the leaf, and so out into the air again. The change may be represented chemically by means of formulae in this way :—

$$\underset{\text{(carbon dioxide)}}{CO_2} + \underset{\text{(water)}}{H_2O} = \underset{\text{(formaldehyde)}}{C\,H_2\,O} + \underset{\text{(oxygen)}}{O_2}$$

$$\underset{\text{(formaldehyde)}}{12\,C\,H_2\,O} = \underset{\text{(cane sugar)}}{C_{12}\,H_{22}\,O_{11}} + \underset{\text{(water)}}{H_2\,O}$$

Now this change only goes on under certain conditions ; first of all, of course, both water and carbon dioxide must be present ; secondly, the green colouring matter is necessary ; thirdly, we must have sunlight. The splitting up of the carbon dioxide and its combination with water is a process that requires the expenditure of a great deal of energy, and in the presence of its green colouring matter, the plant is

able to seize on the energy of the light rays from the sun and convert this into the chemical energy necessary for this process.

DISPOSAL OF SUGAR FORMED.

Part of the sugar thus formed is taken to other parts of the plant and used up as food, just as we consume the starch and sugar present in the food we eat. But a good deal more sugar is formed than is consumed in this way and the excess is stored in the stem. It travels down the leaves constantly, day and night, and when it reaches the stem is stored as sugar in the thin walled cells which fill up the spaces between the strands of wood vessels.

Part of the sugar is also combined with nitrogen and other elements and built up to proteids and finally into the living matter of the plant itself. This process also goes on in the leaf.

Now the formation of sugar in the leaf is the most important point to note in the nutrition of a green plant. All plants and animals require some carbonaceous material, such as starch or sugar, for food, but the green plant alone is able to manufacture this food from simple inorganic bodies —carbon dioxide and water—present in the soil and air.

THE STRUCTURE, NUTRITION AND REPRODUCTION OF A FUNGUS.

Now to compare with the structure and nutrition of a green plant, let us examine the structure, methods of reproduction and mode of nutrition of a fungus. For our example let us

take the common grey mould that appears on damp bread and similar substances, when they are kept in a closed chamber.

STRUCTURE OF MUCOR.

The body of the fungus is very simple in structure; it may be divided into the vegetative part which provides for the nourishment of the fungus, and the reproductive part which provides for its multiplication. The vegetative part of an ordinary green plant is divided into root, stem and leaf, each with its special functions; the vegetative part of the fungus shows no such division. It is composed simply of a network of threads which branch and interweave in all directions. The threads are known as *hyphae* and the branching network that they form as the *mycelium.* Some of the hyphae grow down into the substratum and serve more or less the functions of roots, while the rest spread out on the surface of the substratum. The hyphae are all alike, and the most important point to notice about them is that they possess no green colouring matter, such as is met with in the cells of ordinary green plants.

REPRODUCTION BY SPORANGIA.

When the fungus is about to reproduce, certain hyphae, rather larger than the others, grow up straight into the air instead of creeping along the substratum. The ends of these hyphae swell up and become densely filled with protoplasm, in which we find large quantities of food grains, composed of oils and proteids. Next, a cross wall is formed, cutting off this swollen head from its stalk. Then the living matter in the head or *sporangium* divides up into a number of little pieces; these pieces round themselves off and each provides itself

with a wall and becomes a *spore*. The spores escape by the

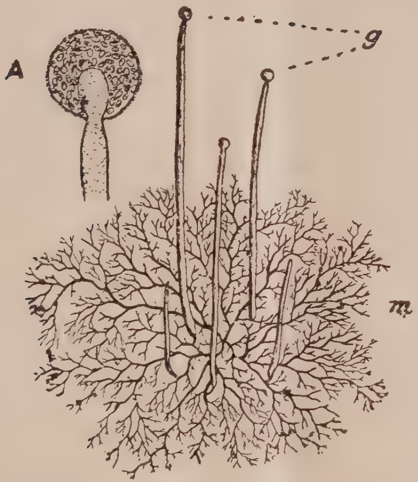

Fig. 1. A plant of a kind of *Mucor* showing the web-like growth at *M* and the stout vertical threads bearing the spherical swellings at *G*. *A*. One of these swellings highly magnified showing the spores in its interior. (After Brefeld.)

bursting of the sporangium and are blown away by the wind. The point to which I would specially draw your attention is the immense number of spores that are produced. On a small piece of bread, many hundreds of sporangia will be developed and each sporangium contains very many spores.

GERMINATION OF SPORES.

Of course by far the greater number of these spores fall

into places unsuitable for their development and die, but their immense numbers ensure that some at least will fall upon favourable conditions ; these are, briefly, a favourable temperature, a supply of food, and a supply of moisture. When a spore does so fall, it starts to germinate : this it does simply by putting out a small hypha at one side which grows and branches and very soon gives rise to a very considerable mycelium again, which presently again begins to form sporangia. A mycelium developed from a single spore and bearing a number of young sporangia is shown in Fig. 1.

REPRODUCTION BY CONIDIA.

There are many other ways in which other fungi reproduce themselves that I will not trouble you with, but there is one method which is of considerable importance from our point of view, that I will describe briefly. When some fungi are about to reproduce, special hyphae are formed as before and their ends become filled densely with protoplasm. The ends do not swell up as before, however, but a small piece at the end is cut off by a cross wall and becomes a spore at once ; sometimes other pieces are subsequently cut off below this, and we get chains of spores. Sometimes these spore-bearing hyphae occur singly and apart from one another, but very often they are massed together in special places and we get what might be called spore beds, on which thousands of spores are produced.

NUTRITION OF A FUNGUS.

The most important point to remember in considering the nutrition of a fungus is that it possesses no green colouring matter. You remember that it is because of the posses-

sion of this green colouring matter that the sugar-cane plant is able to manufacture for itself the sugar it needs as food. The fungus needs the same food as a green plant, consequently, like an animal, it must have its sugar or starch ready made. This is the whole question of the nutrition of fungi and it is this which has caused some of them to become such deadly enemies to green plants. Fungi may obtain this organic food, starch or sugar, in two ways. Some of them are only able to take it in from dead animal or plant remains, bread, boots, jam, dead wood, etc. Others, again, are only able to extract it from living plants and animals, and these, of course, cause diseases of their hosts: they are the exclusively parasitic fungi. A third group can get all the starch or sugar they need from dead organic matter, but they are also able, under certain conditions, to enter living plants and get their food from those as hosts ; these are perhaps the most difficult of all to deal with, as it is very difficult to starve them out. We shall consider this question of parasitism further in my next lecture.

LECTURE II.

In my last lecture we considered the sugar-cane in health; we went briefly through the different organs of the plant and their structure, and studied the part each organ plays in the life of the plant.

DISEASE, ITS NATURE AND EFFECTS.

To-day I want to deal with the sugar-cane in disease, and the first question that arises is—What is disease? Disease may be manifested in several ways; in some cases the whole plant may shrivel up and die at once, in others the growth of the plant is stunted, in many cases disease is manifested by a wilting of the foliage. Other diseases are more local in their effects and we get wounds, cankers, galls, etc., while others are shown by the dying off of definite organs, especially leaves. I think we may call any plant diseased, when any one or more of its organs is not performing its proper functions or not performing them to their fullest extent. Thus the root may be prevented from anchoring the plant in the soil or from absorbing water and food salts; the stem may be prevented from supporting the leaves in the air or from conveying the water from the roots to the leaves; while leaves may be unable to carry out their important functions of the manufacture of sugar, breathing and transpiration; again the flowers may be unable properly to form seeds and fruit.

CAUSES OF DISEASE.

A diseased condition may be brought about in a plant in two ways, or rather by two kinds of causes—internal and external. As external causes of disease I may mention the absence or scarcity of food salts in the soil, the absence of a sufficient quantity of water, or the presence of poisonous substances in the soil, which may be taken in to the plant, all of which prevent the roots from performing their proper functions. Then we may have an improper condition of the soil, which prevents the roots from obtaining the air needed for breathing and so hinders their development. Again the air may contain poisonous substances, which are taken into and hurt the leaves, or it may contain fine, solid particles which block up the stomata.

To-day we are not concerned, directly, with plant diseases that are caused by unfavourable external conditions, but we have to consider those that are brought about by parasitic fungi which live in and upon the sugar-cane plant.

SAPROPHYTIC AND PARASITIC FUNGI.

You will remember that in my last lecture I pointed out that all plants and animals require some carbonaceous food, usually starch or sugar. The green plant is able to manufacture this from simple inorganic bodies—carbon dioxide and water—present in soil and air. The animal and fungus, however, possessing no green colouring matter, require their starch and sugar ready made and so are dependent upon green plants for their food.

Some fungi are only able to make use of dead animal or plant remains: these are the so-called saprophytic fungi.

Others again are able to get their food only from living plants and cannot exist on dead matter: these fungi are the obligate parasites. A third and the largest group are able to live on dead organic matter of various kinds, but they are also able to enter the tissues of living plants and make use of the organic food manufactured by the green plants for their own use; we may call these fungi facultative parasites. You will see at once that they are a difficult group to deal with. An obligate parasite may be starved out by avoiding the cultivation of its own special host plant. These facultative parasites require much more thorough and careful treatment. In order to starve them out, not only must we avoid cultivating the host on infected land, but we must also destroy all dead plants and parts of plants which may serve as resting places or nurseries for the fungus. Unfortunately, most of the fungi that attack and cause disease in the sugar-cane belong to this group.

RIND DISEASE.

The most important of these diseases is the rind disease of the stem, a disease which is historically of great importance in Barbados, as it was the susceptibility of the Bourbon cane to this disease that forced planters in this island to replace this cane by other, more resistant, varieties.

SYMPTOMS OF RIND DISEASE.

The first point that requires attention from a practical point of view is the recognition of the disease. Anyone can tell when a plant is looking unhealthy, but more definite

information is required before it can be told whether a plant is suffering from an impoverished or bad mechanical condition of the soil, poor cultivation, etc., or whether it is attacked by one or other of the fungi causing disease.

Usually the first sign of the disease that is noticed is the gradual drying up of the outer leaves of the top. The leaves turn yellow, first at their margins; the yellow colour gradually extends until the whole leaf is dead and dry. The outer leaves dry up first, but the withering spreads in succession to the younger leaves, until finally the whole top is dry.

If we split a cane in which the drying up of the leaves is just beginning, we shall find one or two internodes of the stem giving distinct evidence of the disease, in that they show a reddish colour. Here and there in the discoloured area we get darker patches, in the centre of each of which is a definite white area.

Later on, the stem shows distinct evidence of the presence of the disease from the outside. Some of the internodes will be seen to have discoloured areas ; these areas are reddish-brown in colour and somewhat sunken, owing to the shrivelling of the tissues underneath. If we cut into the stem at these places, we find the tissues underneath red and brown with whitish spots.

At a later period, during crop time, we find numbers of these 'rotten canes' in estate yards. By this time the whole cane is discoloured and brown, the internodes are shrunken, and the cane shows a large number of tiny, black, hair-like structures. These structures are formed under the rind and burst through this to get to the outer air.

When we take one of these hairs and examine it under a microscope, we find that it is simply a mass of the spores of the fungus causing rind disease ; each hair contains thousands of these spores which are loosely cemented together by a kind of mucilaginous substance. It is by means of these spores that the fungus spreads, and we will take up the study of the fungus (*Trichosphaeria sacchari*) at this point.

GERMINATION OF SPORES OF RIND FUNGUS.

If we sow some of these spores in a drop of water and keep them under observation for a few days, we shall see them begin to germinate. Each spore puts out a small tube (hypha) at one end, which grows a little and branches, at the expense of the food stored away in the spore. In water, this food is soon used up and the hypha dies.

If, however, we sow the spores in some food material, for instance in some sugar-cane extract and gelatine, or on a slab of cane that has been steamed, development proceeds further. The hypha, put out from the spore, grows considerably in length and branches all over the substratum, giving rise to a very considerable mycelium, which eventually again produces spores. The fact that the fungus can be made to grow and reproduce on steamed slabs of cane or on cane extract is of some importance : it proves that the fungus can grow and reproduce on pieces of dead cane which may be lying about on the estate, and so is able to maintain itself even though there are no living canes to be attacked.

ARTIFICIAL INFECTION OF THE SUGAR-CANE.

The next question is, how the fungus enters the sugar-cane plant. You remember in my last lecture I pointed out that the stem of the cane possesses a special layer on the

outside, the epidermis, the outer walls of which are thick, tough and impervious. Some fungi can make their way in through the epidermis: they secrete certain ferments which dissolve this tough outer wall, and so make their way clear to the inside of the plant, even when the epidermis is uninjured. The rind fungus is not one of these. If we sow some spores in a drop of water on the outside of a cane stem, provided that the epidermis is uninjured, no infection results.

If now we take some spores on a needle and stick the needle into the stem, through the epidermis, we get a very different result. The spores germinate and the hyphae now have only to deal with the inner tissues of the plant which they are able to break down. In a short time the infected spot becomes discoloured and shows all the signs of rind disease.

Another experiment will show the same thing. We can make a small wound in the cane by stripping off one of the leaves. Now if we sow some of the fungus spores on this wound, taking care, of course, that no other fungus spores or bacteria are introduced at the same time, the cane is again infected and shows the rind disease.

These experiments show two things clearly. In the first place, they show us that the spores found on rotten canes, when introduced into the cane plant, bring about the rind disease. Secondly, they show us that so long as its epidermis is intact the cane plant is immune to the attack of the fungus.

INFECTION UNDER NATURAL CONDITIONS.

Probably under natural conditions the fungus gains

entrance to the interior of the sugar-cane most often by the tunnels of the moth-borer or of the weevil borer. The spores are produced in immense numbers on rotten canes, as you will have realized ; they are blown about by the wind or become attached to the bodies of ants and other insects which frequent the rotten canes. Of course, the vast majority of them never come into suitable conditions and therefore die, but some of them are sure to be brought to a wound in some way or other, and one spore is capable of causing rind disease in a cane plant. But the tunnels of these insects are not necessary for the entrance of spores. Any small wound, caused by the breaking off of a leaf by wind, or by any other means, is a possible centre for infection, and with the thousands of spores produced the chances of one reaching the wound are fairly high.

GROWTH OF FUNGUS IN SUGAR-CANE.

Now let us see how the fungus lives when once it has started growth inside the tissues exposed by a wound. The hyphae put out from the spore first of all enter the thin-walled cells which, you remember, pack in between the strands of wood vessels. The tip of the hypha probably secretes some ferment which dissolves the thin wall of the cell, and the hypha then grows on into the cell cavity. In this way the hyphae go on, branching and growing, passing from one cell to another, until every cell around the point of infection is filled with the hyphae of the rind fungus.

DAMAGE CAUSED BY THE FUNGUS.

You remember that it is in these cells that the plant stores the excess sugar manufactured in the leaves as a

reserve, the sugar for which we cultivate the sugar-cane, and the sugar the fungus requires as food. Of the three of us the fungus now has the advantage, and it consumes or destroys all the sugar contained in the attacked cells ; the cells are meanwhile killed, they dry up and become discoloured, thus giving rise to the discoloured shrunken areas which are characteristic of the rind disease.

But this is not the only damage done by this parasite. Not only can it dissolve and break through the thin walls of the packing cells, but it can also dissolve the hard, woody walls of the vessels that carry the water current. A hole is bored through the wall of a vessel, and the hypha then passes in and grows and divides in the cavities of the vessel. In this way the fungus is able to intercept, and take for its own use, the water and food salts which are being taken from the roots to the leaves. So far as the plant is concerned, this is a more serious damage than the other. The sugar in the thin-walled cells is a reserve, and so long as the fungus confined its attention to this, the plant would still be able to manufacture all it required for its actual growth and life. But now the supplies of water, etc., are cut off from the leaves, and the plant can no longer manufacture its sugar and proteids. The leaves then begin to die from starvation, the outer ones first, and first their margins, then the death of the tissues gradually goes further until, finally, the whole top of the plant is killed off. The process reminds one of the starving out of a besieged city, where the besiegers have been able to cut off the water and a great part of the food supply, so that it is only a question of time when the besieged people will die off, first those who have the greatest difficulty in getting food, but finally, everybody.

REPRODUCTION OF THE RIND FUNGUS.

Now the fungus proceeds to reproduce itself. Close under the rind of the dying plant, the hyphae begin to branch and interweave vigorously; they draw supplies from the hyphae back in the stem. The cushion of hyphae thus formed becomes a spore bed in the manner I mentioned at the close of my last lecture; the hyphae nearest the surface grow out parallel to one another, and begin to cut off spores; thousands on thousands of these spores are produced, until finally, the pressure on the rind becomes so great that it is burst and the mass of black spores, bound together by mucilage, is pushed out like a curly, black hair. The spores are now ripe and are ready to be carried by the wind or insects to fresh host plants.

Remedial Measures.

Finally, we have to consider our means of fighting this pest, and it is evident that these methods may be divided into two classes: first, those that aim at the destruction of the fungus, and second, those that aim at the encouragement of the host plant. Now the most important thing about these measures is that they must be systematic and regular. It is not a bit of good fighting the fungus energetically for a time and then letting it slide, for with the immense numbers of spores produced, a very little colony of the fungus is capable of infecting a very large area. Again, they must be general. It is not fair to a planter who spends considerable time and care in destroying the fungus, if his neighbour takes no care or trouble but lets the fungus breed on his estate ready to infect the first planter's carefully cleaned land.

DESTRUCTION OF DISEASED MATERIAL.

The first way of fighting the fungus is to destroy all rotten canes. These are the breeding places of the fungus where it produces its spores, and the more promptly they are destroyed, the less chance the fungus has of spreading to healthy canes. Too often, rotten canes are stacked by themselves in the estate yard and the fungus is left to breed; I cannot conceive of any more efficient method of helping the spread of the fungus than this. Sometimes workmen are allowed to carry off the canes for fuel, and sometimes they are used in making pen manure; these practices should never be allowed. All rotten canes should be carefully collected and burnt as promptly as possible; if the canes are worth it, they may be crushed and the megass burnt. If this is carried out thoroughly and regularly, the chances the fungus has of forming spores will be very much reduced.

PREVENTION OF WOUNDS.

Then every effort should be made to prevent the formation of the wounds by which the fungus enters the cane. It is impossible to prevent wounds altogether, but the most dangerous wounds in this respect—those caused by boring insects can be dealt with to a very large extent, if the recommendations made at various times by the Imperial Department of Agriculture are carefully carried out.

ROTATION OF CROPS.

Again, we have the chance of trying to starve out the fungus by a rotation of crops. Where this is systematically carried out, as in England, fungoid diseases give very little

trouble. But we must remember that it is of little good cleaning a piece of land from the fungus, unless at the same time, we try, by all the means in our power, to prevent it from becoming infected again.

SELECTION OF CUTTINGS.

Now for our methods of helping on the host plant. The first of these is to avoid making cuttings from diseased canes. If this be done, the plant is infected as soon as it begins to grow and is doomed ; not only this, but it forms a base on which the fungus can maintain itself, produce spores and infect other plants.

IMPROVED CULTIVATION.

Then we should try by careful and thorough cultivation to get healthy canes. A weak plant, like a man with a feeble constitution, is always more liable to be attacked by, and succumb to, a disease than a healthy plant or man. So by all means in your power help the plant to make a healthy, vigorous growth, so that it will be able to help itself in the struggle with the fungus.

SELECTION OF RESISTANT VARIETIES.

Finally, we have the selection of varieties of canes that will resist the attacks of the fungus. A great deal has been done in this way and is still being done to get improved resistance in varieties of canes. Of course, we cannot expect to get a variety that will be immune to disease, nor a variety that will maintain its resistance in the face of improper methods of cultivation. So by all means plant the most resistant canes you can find, but at the same time cultivate

them, so that they maintain their resistance, and use every other means in your power to prevent the spread of the fungus.

PINE-APPLE DISEASE.

The other disease of which I wish to speak to-day is the so-called pine-apple disease of cane cuttings.

SYMPTOMS OF PINE-APPLE DISEASE.

The effects of this disease are to prevent the germination of the cuttings or to stop the growth of the young shoots soon after they come above ground.

The failure of these cuttings to germinate is usually put down to drought, and it is quite true that the disease is far more abundant in a dry, than in a wet, planting season. This is another example of the fact that the health of the host plant is of the utmost importance in considering the spread of its parasites. In a wet planting season, as we had last year, the cuttings make healthy and vigorous growth and so are able to throw off the disease, but if the season be unfavourable, the plants grow slowly and feebly and so readily fall victims.

On splitting open a diseased cutting a distinct odour of pine-apples is noticed, and the cutting is seen filled with a black, mouldy mass composed of the hyphae and spores of the fungus (*Thielaviopsis ethaceticus*).

INFECTION OF CUTTINGS.

If we take some sound cuttings, dip them in water, which contains some of these spores, and then plant these

cuttings, we find that they all have been infected with the disease. Infection takes place at the ends of the cuttings or at bruises and wounds, anywhere, in fact, where the cutting is not protected by its epidermis.

Protection of Cuttings.

The next question is how to protect the cuttings from the attacks of the fungus. Numerous experiments have been carried out to test the effect of various substances in this way. Some experiments were carried out by Mr. Howard in Barbados to test the effect of immersing the cuttings in water, lime wash, dilute carbolic acid and Bordeaux mixture, also the effect of tarring the cut ends either with or without previous treatment with Bordeaux mixture.

The results of the experiments were published in full in the *West Indian Bulletin* (Vol. III, p. 73), but briefly put, they showed that by far the best way to treat cuttings was to immerse them, as soon as prepared, in Bordeaux mixture for six to twelve hours, then allow them to dry and tar the cut ends. Bordeaux mixture alone also gave very good results. The cost of the double treatment he worked out at $12 per 100 acres.

EXPERIMENTS IN BARBADOS.

It is still a question whether this treatment will pay when carried out on an estate scale. To test this, Mr. Bovell carried out some experiments during the last planting season in December 1902. The results have already been given in the *Agricultural News* (Vol. II., p. 99), and are inconclusive. The experiments were carried on in ten series to show the

results of treating cuttings with tar, and of covering them with $\frac{1}{4}$ inch of soil.

RESULTS.

Owing to the very favourable weather which prevailed at the time, from 72 to 81 per cent. of all the cuttings germinated. This shows that in a favourable season it does not pay to tar the ends. It still remains to be seen whether it will do so in a dry season and, then, taking wet and dry seasons together, whether the treatment is worth adopting as a general thing.

EXPERIMENTS IN ANTIGUA.

During the planting season of 1902-3, some experiments, based on Mr. Howard's recommendations, were carried out by the Hon. Francis Watts, at Cassada Garden estate, in Antigua. The results were published recently in the Report on Sugar-cane Experiments in the Leeward Islands, from which the following summary is taken :—

In each experiment 100 plants or cuttings were planted. There were four series, one series remained untreated, in one the plants were treated with Bordeaux mixture for two hours; in the third the ends were tarred, and in the fourth the plants were first treated with Bordeaux mixture and the ends tarred.

In each series 100 plants were planted nearly vertically at such a depth that the ends were covered with soil; another 100 were planted nearly vertically but the ends were left uncovered; a third 100 were planted flat. This gives twelve experiments, and each of the twelve was carried out in one case with tops and in the other case with cuttings.

RESULTS.

Mr. Watts sums up the results briefly as follows :—

'*Bordeaux mixture:* This is the most efficient of the agents experimented with, its influence being most strongly marked when "cuttings" are used for plants. Without it, i.e., of the untreated cuttings, less than 20 per cent. survived, while 75 per cent. of treated cuttings grew. With tops thus treated 96 per cent. grew, while only 61 per cent. of untreated ones survived.

'*Tarring the ends:* This was of no benefit in connexion with tops, and of but very slight benefit with cuttings.

'*Bordeaux mixture and tarring the ends:* This treatment did not produce any better, or even such good, results as those obtained from the use of Bordeaux mixture only.

'From which we conclude that Bordeaux mixture, when used alone, is an efficacious agent in preserving cane tops and cuttings until they germinate; that the treatment is particularly useful where cuttings are used, and a high mortality may be feared; and that this treatment will probably be useful when drought may be feared, or where canes are planted in areas liable to fungoid attack.'

It does not appear that a comparison was made between cuttings treated in the ordinary estate way—with water, lime wash or dilute carbolic acid and those treated with Bordeaux mixture. So we still want conclusive experiments, carried out on the estate scale, to show the effect of Bordeaux mixture.

USE OF SOUND CUTTINGS.

There is another preventive method which should be generally adopted, and that is to avoid planting cuttings which show any wounds, especially those caused by the moth or weevil borer. These cuttings will probably be infected before they are planted and give the fungus a good start. So that, as in the case of the rind disease, only perfectly healthy and sound cuttings should be planted.

OTHER SUGAR-CANE DISEASES.

There are a few other fungi causing cane diseases, some of which attack the leaf, others the leaf-sheath, and damage the plant by destroying a certain amount of leaf-tissue in which sugar formation is going on; but they do comparatively little damage and are economically of small importance.

The root disease, which at the present time is the most important of all the fungoid diseases of sugar-cane in the West Indies, I shall consider in my next lecture.

LECTURE III.

ROOT DISEASE OF THE SUGAR-CANE

In my previous lectures, I spoke first of the sugar-cane in health, and then of it as attacked by two of the more important stem diseases, the rind disease and the pine-apple disease. With both of these diseases we found we could deal; the rind disease has, for the present at least, been kept under by the use of resistant varieties of cane, the White Transparent and various seedling canes; the pine-apple disease of cuttings has been proved, on an experimental scale, to yield to treatment with Bordeaux mixture.

IMPORTANCE OF ROOT DISEASE.

There still remains to be considered the root disease, a disease which has probably caused more damage during the past few years than all other sugar-cane diseases together. It appears to attack equally well all varieties of cane at present in cultivation and yields to no fungicidal treatment. It is a most interesting disease from the point of view of the plant pathologist, in that I know of no other in which host and parasite are so evenly matched, so that a small disturbance in the external conditions may very easily lead to one or other getting the upper hand, and possibly it is this that

makes some planters appear unwilling to assist the sugar-cane in what appears to be a fair fight. But it is precisely this weakness, if I may put it so, in the parasitic qualities of the *Marasmius*, that makes it such an insidious and dangerous enemy, and, moreover, so difficult a one to deal with.

Symptoms of Root Disease.

The fungus attacks ratoons more frequently than it does plant canes, but it is often to be found on plant canes, although it may be doing comparatively little damage.

The symptoms of the disease are well marked, and if careful examination be made of the canes suffering from it, there is no chance of its being mistaken for any other.

LEAVES.

The leaves first show signs of the disease ; instead of a dozen or so broad, bright-green leaves we get fewer leaves and these drying up much earlier than they should do. The drying up takes place first at the tip and edges of the leaf and gradually spreads until the whole leaf is dry and withered. The younger leaves, before even they begin to turn yellow, do not open out as they should do; they remain partially rolled up, in the manner I spoke of in my first lecture. Evidently the plant is suffering from lack of water, the leaves farthest from the main axis, and first the parts of them which are farthest removed, are drying up and dying, while the younger leaves, which are still receiving a certain amount of water, roll up to reduce the water lost by the process of transpiration. These then are the first noticed symptoms of root disease ;

but it may be said they might equally well be due to drought. This is quite true, but it will be noticed that other plants in the same field and exposed to exactly the same conditions, do not show them or show them to a less extent.

LEAF-BASES.

If now we examine the bases of such plants we find still more marked characteristics of the disease. The old dry leaf-sheaths, which in a healthy plant are thrown off, leaving the base of the stem clean, remain attached and require considerable power to remove them. On examination, we find that they are all matted together by a clean-looking, white felt which is the mycelium of the fungus *Marasmius*. The matted leaf-bases have a characteristic musty smell.

ROOTS.

Pulling off this mass of dead leaf-bases, we notice at once that the roots, which normally spring from the nodes, burst through the leaf-bases and then grow down into the soil, are not developing properly. Either these roots do not develop at all or their growth ceases when they are about $\frac{1}{4}$ to $\frac{1}{2}$ inch long. The tips of these aborted roots are reddish or blackish in colour. The undeveloped roots are indicated by brownish spots in the rind of the cane.

EFFECTS ON GROWTH.

The canes attacked by the root fungus are usually considerably dwarfed in comparison with others in the same field; not only are fewer leaves developed but the stems are much thinner and drier and usually shorter than normal canes.

Again, the diseased canes are very easily uprooted ; the slightest pull is sufficient to remove the stool : whereas, as you know, considerable force is required to uproot a healthy stool of canes.

Finally, from the base of the stool, or from the roots, arise the fruits of the fungus which causes the root disease. These are small, white or yellowish toad-stools and one usually finds them in groups. They are rarely to be found except in wet weather and the best time to look for them is in the early morning before the sun has dried them up.

Fig. 2. A portion of the base of a sugar-cane, attacked by root disease, bearing the toad-stools of the fungus (*Marasmius sacchari*) which causes the disease. (From *Nature*.)

With all these points characteristic of the disease, there ought to be no difficulty in recognizing it wherever it occurs.

STRUCTURE OF TOAD-STOOLS OF MARASMIUS.

The toad-stools are the spore-bearing parts of the fungus and so their structure demands our special attention. Each one consists of two parts—a slender stalk or *stipes*, and a cap or *pileus*. On the under side of the cap there hang down a number of gills or *lamellae*; these lamellae are regularly arranged radiating out from the centre of the cap, near the insertion of the stalk, to the margin; they are occasionally branched. Both cap and stalk are, of course, composed of hyphae which are all alike or nearly so, but the hyphae differ from those of the other fungi we have examined, in being far more regularly arranged. In the stalk, although they branch and interweave, so giving firmness to the mass, the general course of the hyphae is vertical and they run approximately parallel to one another. Similarly in the cap the hyphae generally run regularly, radiating out from the point where the stalk is attached to the margin, while some of them turn down and form the gills. The structure of the gill also demands our attention as it is upon it that the spores are formed. To see its structure we cut a section tangential to the cap, in which way, of course, we get a cross section of the gills.

STRUCTURE OF GILLS.

In the centre of the gill we get hyphae running more or less parallel down from the cap. Those near the edge turn out at right angles to the general direction and the ends of

these hyphae become the spore-bearing organs of the fungus, which are here known as *basidia.* These basidia have a special structure which is constant through and characteristic of the highest group of the fungi, the Basidiomycetes, to which the mushrooms, toad-stools and puff-balls belong. A basidium is a club-shaped hypha, at its free end it puts out a definite number of tiny branches, the *sterigmata,* at the end of each of which a single spore is formed. The number of spores formed on each basidium is thus a definite one. In *Marasmius,* as in most cases, it is four ; sometimes it is two or eight, but for any Basidiomycetous fungus it is a definite number. These basidia form a definite layer on the outside of the gills, which they cover like a palisade tissue.

We thus see that the structure of the spore-bearing part of *Marasmius* is a highly specialized one. We find the gill has a definite structure, a central part, the *stroma,* then a definite *subhymeneal layer,* where the hyphae are turning out, and then a definite *hymenium* composed of the basidia ; the basidia again are definite in size and form and bear a definite number of spores.

NUMBER OF SPORES PRODUCED.

Now I wish you to notice the immense number of spores that are produced. Every gill is covered by closely packed basidia, each one of which produces four spores. We can get some idea of the number by taking off the cap from its stalk, and laying it flat upon a piece of black paper and covering it with a bell-jar or anything that will keep off the wind. The spores, which are white, fall on the paper as they ripen and give a print of the gills, which can be fixed by gum

arabic. When you reflect that the mass of white powder is composed of spores, which are so small as only to be distinguishable with a microscope, you will get some idea of the myriads of spores found on each toad-stool.

SPREAD OF FUNGUS BY SPORES.

Now one of the ways in which the root fungus spreads from plant to plant is by means of these spores. Under natural conditions the spores are shed at the base of the cane plant and are thence carried away either by wind or insects. As each spore is capable, if conditions be favourable, of infecting a cane plant with root disease, it does not require much imagination to realize that those canes near a group of the toad-stools have a very good chance of becoming infected, if only by this means, while there is quite a fair chance of the light spores being blown by the wind to canes at a greater distance.

GERMINATION OF SPORES.

The spores form a good starting point fróm which to begin the study of the life of the fungus. They will germinate in a drop of water on a cover slip and then each puts out a short hypha and no more. If we remove this hypha on the end of a sterilized needle to a sterilized slab of cane in a tube, it will go on growing. Compared with those of the rind fungus, the hyphae are small and very closely woven ; moreover, their growth is much slower. Another point about these hyphae, which is characteristic of all Basidiomycetes, is their possession of clamp connexions, which put the segments of a hypha into closer connexion one with another.

INFECTION OF SUGAR-CANE BY SPORES.

Now imagine what happens when one of these spores is carried by the wind and gets on a cane plant. In all probability it will fall on one of the leaf-sheaths and will lodge somewhere between the sheath and the stem. Here it has a nice sheltered situation, plenty of moisture and a supply of food. The chances are that the spore will germinate and soon give rise to a mycelium, which at first grows in, and obtains its nourishment from, the dead and dying tissues of the leaf-sheaths. It passes from one of these to another and, by its dense matted habit of growth, binds them all together in a close, decaying, musty smelling mass, in the manner that is doubtles familiar to everybody here. In a similar way, the fungus spreads to any dead or dying part of the plant above or below ground. The older roots, and other old dead parts of the cane plant in the soil are all infected and permeated by the mycelium of *Marasmius*.

The fungus now holds a position, as it were, surrounding the attacked plant, and simply watches its opportunity for doing it damage. When this comes, it is the young growing root that is attacked and this is entered at its most vulnerable and most important part and that is the growing point.

ATTACK OF FUNGUS ON ROOTS.

You remember that the growing region of the root is composed of a number of very delicate, thin-walled cells, full of protoplasm and actively dividing. Constant supplies of sugar and other food materials are continually being sent down from the leaves to be used up in the formation of new tissues, which takes place here and only here in the root.

You see then, that the growing point forms a very nice source of food for the fungus, plenty of food-supply and only very thin, delicate cell walls to break through in order to get it. The growing point is covered by a cap of dead cells—the root cap, which serves to protect it from mechanical injury by the particles of soil, but the root cap is no protection against the attacks of a root fungus like *Marasmius*. The hyphae penetrate in and among the dead and dying cells of the cap and draw nourishment from them, just as they do from the dead tissues outside the plant—the trash, etc.

EFFECT ON PLANT OF FUNGUS ATTACK.

The fungus does no other damage and attacks no other part of the plant ; it simply enters the tissues of the growing point and destroys them. This is the cause of the dark colour of the root-tips which I mentioned as one of the symptoms of root disease. But you will see that this is quite enough to affect seriously the growth and nourishment of the cane. It is at the growing point alone that the formation of fresh tissues takes place; consequently, when this is destroyed, the growth of that root is stopped. I explained in my first lecture how the older roots of the sugar-cane are continually dying away and that these are replaced by new roots which are continually being developed. Now if these new roots are constantly destroyed as soon as they start their growth, the plant must endeavour to replace them again by other roots, and so continually draws on its food material. Meanwhile, the plant is continually getting less and less able to supply the food required. As roots die away and are not replaced by others, the water and mineral salts from the soil are absorbed in gradually decreasing quantities, consequently the leaves

are unable to manufacture so much of the sugar and proteid substances, which are required for use during growth.

EFFECT ON ABSORPTION AND GIVING OFF OF WATER.

The first sign of the disease is due to the cutting off of a part of the water supply. At this time the leaves have not begun to suffer and so are transpiring freely, while the roots are not taking in the full amount of water. The effect on the plant is the same as that of excessive drought. The leaves under these conditions roll up in order to lessen the loss of water by transpiration, and with plants infected with root disease this condition becomes more or less permanent. In this way, a balance is struck between the absorption and the loss of water. But you will see at once that the state of these plants is not a healthy one.

EFFECT ON FOOD SUPPLY.

In the first place, if the water current be reduced, so must be the supply of nitrates and other mineral salts from the soil which travel in it. In the second place, the same mechanism that will protect the stomata from giving out their full amount of water vapour into the air must, of necessity, prevent them from taking in the full amount of gases from the air—they are, in fact, shut off from free communication with the outer air. The most important of these gases is carbon dioxide, from which the plant obtains its carbon which it requires for the manufacture of sugar and all organic foods.

So you see, one of the first indirect actions of the root disease is to affect the activity of the leaves and to prevent the free formation of sugar and other organic matter.

In this way, the food supplies of the plant are attacked at both ends, at the roots, and the leaves, and this at a time, it must be remembered, when the plant requires more food than usual in order to replace the roots which are being killed off by the fungus.

STARVATION OF SUGAR-CANE PLANT.

The fungus has now established itself on its host. The latter gradually becomes weaker and weaker, owing to the process of slow starvation I have described. You will understand, now, how the external signs of the root disease are brought about. The stunted habit of the plant is due to inability to form new organs properly owing to lack of nourishment, while the ease with which the plant is uprooted is due to the non-development of roots, which are the anchoring as well as the absorbing organs of the plant.

REPRODUCTION OF FUNGUS BY TOAD-STOOLS.

Later on in the year, usually during the wet season, the fungus proceeds to reproduce itself. This is done by putting out the small toad-stools, the structure of which I have already described, on which the spores are borne. These toad-stools usually grow out near the ground, either from old dead roots or from the trash, etc., at the base of the stem.

RESISTANCE OF SUGAR-CANE.

The cane does not, of course, always succumb to the attack of the fungus in the manner I have described, and you can easily understand how this may be. The fungus

will establish itself, as before, on the old leaf-sheaths and other dead parts and be ready to attack the roots. But suppose a plant cane is growing vigorously and under favourable conditions, it will be able to form new roots so abundantly and so fast that the attack of the fungus produces little effect on them. The same thing, of course, may happen after the fungus has commenced to do damage, if the conditions change and become such as favour root development.

But in both cases the fungus is there; it is not killed off but exists as a saprophyte on the outside of the plant: it is simply 'biding its time'. Now suppose a dry spell sets in; root development is checked; fewer roots are formed and these grow more slowly and less vigorously. The fungus will be able to set in and destroy those that are formed, and that at a time, you will see, when the plant is in urgent need of a complete root system to extract all the available water from the soil.

ATTACK OF FUNGUS ON RATOONS.

A plant cane may and often, I might even say usually, does recover, in part at least, from the root disease, unless the season is exceptionally unfavourable. But if this cane is allowed to ratoon, the conditions are at once changed entirely to favour the fungus. It has a good hold in the dead tissues of the old cane stump: the weather is usually very dry, and the soil, not being cultivated, is tightly packed. Under these conditions the growth of the buds at the base of the cane stump is very slow and the conditions, both as regards moisture and aeration are entirely unfavourable to the vigorous and rapid

growth of roots. Consequently the fungus is able to attack and destroy the majority of the roots put out, and when the rains come, the plant is not in a position to take advantage of the abundant water supply. The ratoon, in fact, never gets a fair start, and in consequence its growth throughout is weak and slow.

SPREAD OF FUNGUS BY MYCELIUM.

Hitherto we have considered the fungus as attacking a single plant, and there still remain the methods by which it spreads from one host plant to another, and the manner in which it remains in a field and tides over from one crop to another.

The spores, of course, are one means by which the fungus spreads from one plant to another. But these are not produced all the year round and they do not account, entirely, for the gradual way in which the disease spreads, from an infected plant as a centre, in ever widening circles.

The fungus travels underground by its mycelium. As I have already mentioned, the mycelium is able to live on dead organic matter and there is always plenty of decaying cane trash and similar matter in the soil. The mycelium then grows along, starting from an infected plant, to one piece of trash after another until it comes near another cane. It proceeds to infect this in the same manner as if it had been developed from a spore.

INFECTED FIELDS.

In the same way a field remains infected with the disease. Any old cane stump or piece of trash is a sufficient source of nourishment for the mycelium and on these the

toad-stools may be produced. If then any infected stump is brought near a growing cane, the mycelium passes from one to another and so the story goes on.

Remedies.

Now let us see what remedial treatment we can bring to bear on this disease.

FUNGICIDES.

In the first place treatment of the soil with fungicides has been proved to do no good, as all those tried have been shown to have no effect on the fungus. Even if they had, the treatment could hardly be carried out on an estate scale.

IMPROVED CULTIVATION.

We must, in every possible way, increase the vigour of the canes. I have already pointed out that a cane growing vigorously is not likely to be damaged, seriously, by the root fungus. The soil should, therefore, be cultivated as thoroughly as possible, so as to give the roots the best chance of developing and at the same time to weaken the fungus.

CULTIVATING RATOONS.

The question of cultivating ratoons has been brought forward, but in Barbados it has been found that the reduction of the capillarity of the soil caused by forking, and possibly also the disturbing of the stumps in the process, do more harm than the resulting aeration of the soil does good. So that in the drier districts of the island the tilling of ratoons is generally found to do harm, though in the wetter districts it sometimes does good.

ISOLATION OF DISEASED CANES.

When only a small patch in a field is attacked and the disease is noticed in time, this area should be isolated from the rest of the field to prevent the fungus spreading by its mycelium underground. This can be done by digging a trench around the area, to such a depth that it goes below the level of the roots of the canes, that is about a foot or so. In this isolated area should also be included one or two rows, all round, of apparently healthy canes.

USE OF HEALTHY CUTTINGS.

Again the utmost care should be taken in selecting cuttings for cane plants. These should come from the very healthiest and strongest canes available. If this be done, not only will direct infection of the young plant be avoided, but there is just the possibility that in this way you may obtain canes which are more resistant to root disease. The same care should be used in selecting plants for supplying. I have seen plants used for this that were badly infested with root disease, in this way forming a centre from which the fungus could spread to the surrounding healthy plants.

RATOONING.

Then we have the question of ratoons. My own opinion is that whenever a plant or a field is attacked by root disease, it should not be allowed to ratoon. Many people, however, will prefer to take their chance, unless the canes, as plants, have suffered badly ; there is of course the chance that, with vigorous plants and favourable conditions, the ratoons may pull through, but I think that, with the present system of cultivation, the odds are against them, and

a badly attacked ratoon crop gives the fungus a fresh hold on the soil.

DESTRUCTION OF INFECTED MATERIAL.

Then we have the disposal of infected material. In the case of human diseases all such matter is destroyed by burning or deep burial. The same should be done with matter from diseased plants ; none of it should be allowed to come in contact with healthy canes. All cane stumps infested with the *Marasmius* mycelium should, if possible, be burnt, otherwise they may be buried, mixed with lime, but not in a cane field. Trash from infested fields should not be used in cane fields, nor should it be made into pen manure which is to be applied to canes. It may be used on land which is to be planted in cotton or in any other crop which is not liable to root disease.

ROTATION OF CROPS.

Again land which has borne a badly attacked crop of canes should be rested for two or three years. With a one crop system, such as still obtains to a great extent, here, it is difficult to rest the land for a sufficient time to starve out the fungus. Cotton, however, offers itself as a remunerative crop and I look upon it as one of the chief advantages of the introduction of this cultivation, that it offers planters a chance to rest badly infested fields for a year or even two years.

POSSIBILITY OF RESISTANT VARIETIES.

Finally we have the possibility of raising varieties of cane which are resistant to root disease. This is the means

by which we were freed from the rind disease. So far as I have seen, however, we have still to find a cane resistant to root disease. There is always the possibility of one being found as is shown by the raising of varieties of cotton resistant to wilt, which is another soil fungus. Planters themselves can and must assist in this, by observing whether any varieties, when planted on an estate scale, are more resistant to root disease than others, and publishing their results.

NEED FOR THOROUGHNESS.

In conclusion, I wish to point out that none of the methods I have recommended will kill out the root fungus, they will only keep it under. It follows then, that for them to be of any use they must be carried out thoroughly and systematically and continually, as part of the routine of estate work. The moment your efforts slacken, the fungus will again begin to take the upper hand and will soon be as bad as if nothing had been done.

Summary.

A green plant obtains its food from two sources, the soil and the air. From the soil, the plant obtains its water and the mineral salts dissolved in it; these are passed up to the leaves. From the air, the plant obtains its carbon; this is taken in from the carbon dioxide of the air, and is combined with water taken in by the roots to form sugar.

A fungus consists of a vegetative part, or 'mycelium,' and a reproductive part. The reproductive bodies are called 'spores'; they are formed in various ways, generally in immense numbers. A fungus possesses no chlorophyll; it is, therefore, like an animal, dependent upon green plants for its organic food. Fungi that obtain this from living plants are parasites; those that obtain it from dead animal or plant remains are saprophytes; many fungi are capable of existing either as saprophytes or parasites according to conditions

RIND DISEASE.

The spores of the rind fungus enter the cane at a wound. They germinate, putting out hyphae which enter first the thin-walled cells containing stored sugar. The hyphae afterwards enter the wood vessels and intercept the water current, so preventing the leaves from obtaining the water and mineral salts, which are necessary for the proper

performance of leaf functions. The spores of the fungus are formed in immense numbers under the rind of the cane; this is finally broken through and a mass of spores emerge, all cemented together.

All rotten canes should be destroyed; boring insects, which produce wounds, should be got rid of; only perfectly healthy cuttings should be used for planting; the best cultural methods should be pursued. At present the rind disease is largely kept under by the use of resistant varieties of cane, which have, in Barbados, to a great extent replaced the Bourbon.

PINE-APPLE DISEASE.

The pine-apple disease attacks cuttings and prevents their proper development. It is more abundant in a dry than in a wet planting season. Experiments, on a small scale, seem to show that dipping the cuttings in Bordeaux mixture and then tarring the ends will prevent infection.

ROOT DISEASE.

The root disease is caused by a fungus, *Marasmius sacchari*, which enters into, and destroys, the growing point of the root tip. The fungus is capable of existing as a saprophyte, and the mycelium is found on dead and dying parts of the cane plant, as well as on decaying vegetable matter in the soil.

The leaves of attacked plants dry up, first at the tip and edges; the dry leaf-sheaths, at the base of the plant, do not fall off clean, but remain attached to the stem and matted together; the canes are dwarfed, and are

easily uprooted. The fungus produces small, white toad-stools near the ground, in wet weather; on these are borne the spores of *Marasmius*. The fungus spreads by the spores, and to a greater extent by its mycelium which grows underground from one cane to another.

The root fungus is not able to do much damage to a cane plant which is growing vigorously, under favourable conditions; it waits for an opportunity when the conditions are unfavourable to root development; this usually occurs when the plant canes are cut back and allowed to ratoon.

Very careful attention should be paid to cultivation, so that the soil conditions may be as favourable as possible to root development; a small diseased area should be isolated by a trench, 12 to 18 inches deep, which should include one or two rows of apparently healthy canes; the strictest attention should be given to the selection of 'plants' and 'tops', these should never be taken from an infected cane plant or even from an infected field; all infected cane stumps should be burnt or buried with lime; the greatest care should be taken that no infected trash is ever used on a cane field; canes infected with root disease should not be allowed to ratoon; badly infested land should be rested, for two or three years, from cane. There is a possibility of raising resistant varieties of cane, and special attention is being devoted by the Imperial Department of Agriculture towards this end.

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